OPEN-FILE REPORT 98-14

SEISMIC HAZARD EVALUATION OF THE BEVERLY HILLS 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

1998

DEPARTMENT OF CONSERVATION
Division of Mines and Geology

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CONTENTS

ILLUSTRATIONS

PREFACE

With the increasing public concern about the potential for destructive earthquakes in northern and southern California, the State Legislature passed the Seismic Hazards Mapping Act in 1990. The purpose of the Act is to protect the public from the effects of strong ground shaking, liquefaction, landslides or other ground failure, and other hazards caused by earthquakes. The program and actions mandated by the Seismic Hazards Mapping Act closely resemble those of the Alquist-Priolo Earthquake Fault Zoning Act (which addresses only surface fault-rupture hazards) and are outlined below:

1. **The State Geologist** is required to delineate the various "seismic hazard zones."

2. **Cities and Counties**, or other local permitting authorities, must regulate certain development "projects" within the zones. They must withhold the development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans.

3. **The State Mining and Geology Board (SMGB)** provides additional regulations, policies, and criteria to guide cities and counties in their implementation of the law. The SMGB also provides criteria for preparation of the Seismic Hazard Zone Maps (Web site http://www.consrv.ca.gov/dmg/shezp/zoneguid/) and for evaluating and mitigating seismic hazards.

4. **Sellers (and their agents)** of real property within a mapped hazard zone must disclose at the time of sale that the property lies within such a zone.

As stated above, the Act directs the State Geologist, through the Division of Mines and Geology (DMG) to delineate seismic hazard zones. Delineation of seismic hazard zones is conducted under criteria established by the Seismic Hazards Mapping Act Advisory Committee and its Working Groups and adopted by the California SMGB.

The Official Seismic Hazard Zone Maps, released by DMG, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available from:

> BPS Reprographic Services
> 149 Second Street
> San Francisco, California 94105
> (415) 512-6550

Seismic Hazard Evaluation Reports, released as Open-File Reports (OFR), summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These Open-File Reports are available for reference at DMG offices in Sacramento, San Francisco, and Los Angeles. Copies of the reports may be purchased at the Sacramento, Los Angeles, and San Francisco offices. In addition, the Sacramento office offers prepaid mail order sales for all DMG OFRs. **NOTE: The Open-File Reports are not available through BPS Reprographic Services.**

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Seismic Hazard Evaluation Reports and additional information on seismic hazard zone mapping in California are available on the Division of Mines and Geology's Internet homepage:
http://www.consrv.ca.gov/dmg/shezp/

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

The Act also directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. They also directed DMG to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that the 1) process for zoning liquefaction hazards remain unchanged and that 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Evaluation Report summarizes the development of the hazard zone map for each area. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historic high-water-table information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the Beverly Hills 7.5-Minute Quadrangle (scale 1:24,000).

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Beverly Hills 7.5-Minute Quadrangle, Los Angeles County, California

By

Mark J. De Lisle

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Beverly Hills 7.5-minute Quadrangle (scale 1:24,000). This section and Section 2 addressing earthquake-induced landslides are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazards zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Liquefaction-induced ground failure has historically been a major cause of earthquake damage in southern California. During the 1971 San Fernando and 1994 Northridge earthquakes, significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated granular sediments at depths less than 40 feet subsurface. These geological and ground-water conditions exist in parts of southern California, most notably in some densely populated valley regions and alluviated floodplains. In addition, the opportunity for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region in general, as well as in the Beverly Hills Quadrangle.

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils is generally confined to areas covered by Quaternary sedimentary deposits. Such areas consist mainly of alluviated valleys, floodplains, and canyon regions. The evaluation is based on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth data, most of which are gathered from a variety of sources. The quality of the data used varies. Although the selection of data used in this evaluation was rigorous, the State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth and thickness of liquefiable sediments, depth to ground water, rate of drainage, slope gradient, proximity to free-face conditions, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to determine the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction potential, opportunity, susceptibility, and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The Beverly Hills Quadrangle covers approximately 62 square miles in southwestern Los Angeles County. Portions of the cities of Beverly Hills, Santa Monica, West Hollywood, Culver City, and Los Angeles, as well as unincorporated areas of Los Angeles County, lie within the quadrangle. The University of California Los Angeles (UCLA) campus is located just north of the center of the quadrangle, near the Los Angeles community of Westwood, about 11 miles west of the Los Angeles Civic Center.

The northern part of the quadrangle is dominated by hilly and mountainous terrain of the southern slope of the eastern Santa Monica Mountains, which contain peaks greater than 1600 feet in elevation. The crest of the west-trending Santa Monica Mountain range lies near the northern border of the quadrangle. Numerous steep-sided, north-trending ridges extend from the crest to the coastal plain of the Los Angeles basin. An older dissected alluvial surface, the Santa Monica plain of late Pleistocene age, lies along the southern flank of the Santa Monica Mountains. This surface, which was formed by several large coalescing alluvial fans, and has been dissected by erosion and the resultant channels filled with Holocene deposits.

Immediately south of the Santa Monica plain are the Cheviot Hills, an erosional surface extending westward from Beverly Hills into the southern part of the City of Santa Monica. Cheviot Hills and this westward extension, the Ocean Park plain, are moderately dissected low rolling topography of late Pleistocene age. Along the present course of Ballona Creek, an ancestral west-flowing Los Angeles River dissected the southern side of the Cheviot Hills and the northern side of the Baldwin Hills forming Ballona Gap. Holocene alluvial materials have been deposited in the gap. The Baldwin Hills occupy the southeastern corner of the quadrangle and have been severely dissected, with relief of about 400 feet above Ballona Gap. The Baldwin Hills and Cheviot Hills represent the nothernmost uplifts of the Newport-Inglewood structural zone.

For the most part, the area south of the Santa Monica Mountains has been heavily urbanized. The main drainage courses within the quadrangle are Ballona Creek, Santa Monica Canyon, Sepulveda Canyon, Dry Canyon, Stone Canyon, Brown Canyon (Beverly Glen), Benedict Canyon, Peavine Canyon, Higgins Canyon, Franklin Canyon and Coldwater Canyon.

GEOLOGIC CONDITIONS

Surface Geology

A compiled digital geologic map of the Beverly Hills Quadrangle was obtained from the U.S. Geological Survey (Yerkes, 1997). The contacts between bedrock and alluvium from the digital file were extensively modified to conform to the topographic contours of the USGS 7.5-minute quadrangle. Additional sources of geologic and engineering geology information used in this evaluation include Hoots (1930), Poland and others (1959), Castle (1960), Tinsley and Fumal (1985) and Dibblee (1991). Geologic maps show that rocks exposed in the Santa Monica Mountains are chiefly igneous, metamorphic, Cretaceous and Tertiary sedimentary rocks; whereas rocks exposed in the Baldwin Hills are dominantly marine deposits of Pleistocene age (for detailed descriptions of these units see Section 2 of this report). Surficial sediments mapped in the area consist of upper Pleistocene marine strata of sand, clay, gravel and conglomerate occupying two areas between Santa Monica Boulevard and Venice Boulevard and older Quaternary alluvial fan deposits forming the broad Santa Monica plain, which extends westward from the City of Beverly Hills. Young Quaternary alluvium has been deposited in the area of the City of Beverly Hills and within and adjacent to the Holocene drainage system. Along the shoreline are beach deposits, and adjacent to the beach, sand dunes are mapped locally. The generalized geology of the Beverly Hills Quadrangle is diagramatically portrayed on Plate 1.1.

Subsurface Geology and Geotechnical Characteristics

Several hundred borehole logs from subsurface investigations within the Beverly Hills Quadrangle were collected at: the California Department of Transportation (CalTrans); the California Regional Water Quality Control Board – Los Angeles Region; DMG Environmental Review and Hospital Review Projects and the USGS. The USGS supplied copies of paper logs collected from the Los Angeles County Department of Public Works storm drain investigations.

Borehole log selection was limited to boreholes drilled in canyons and areas underlain by Quaternary sedimentary deposits. Lithologic, soil test, and related data reported in the logs from about 200 boreholes were entered into the DMG geographic information system (GIS) database. The remaining logs were reviewed during this investigation to aid with the stratigraphic correlations. Locations of all exploratory boreholes entered into the database are shown on Plate 1.2.

Descriptions of characteristics of geologic units recorded on the borehole logs are given below. These descriptions are necessarily generalized but give the most commonly encountered characteristics of the unit.

Older marine deposits (Qom?)

Older marine deposits make up much of the Cheviot Hills and the Ocean Park plain, underlying the area between Santa Monica Boulevard and Venice Boulevard. This material is medium dense to dense fine sand, silty sand, silt and clay with some gravel.

Older alluvium (Qoa)

Older alluvium in the Beverly Hills Quadrangle makes up the broad high Santa Monica plain along the south flank of the Santa Monica Mountains from Beverly Hills west to the edge of the quadrangle. This material consists of alternating beds of medium dense to very dense sand, clay and silt. Gravel is abundant in many layers.

Eolian deposits (Qe?)

Eolian deposits mapped immediately inland from the modern beach are composed of a very thin layer of fine sand, less than 10 feet thick on borehole logs. This deposit is typically underlain by dense to very dense sand of older alluvial deposits.

Beach sand (Qm)

Onshore from Santa Monica Bay is a clean, well sorted, medium sand.

Younger alluvium (Qya, Qya1, Qya2)

The younger Quaternary alluvial deposits can be differentiated by their geomorphic relationships and have been mapped as Qya, Qya1 or Qya2. In the subsurface, based on the geotechnical parameters, it is not possible to distinguish among the generations on an alluvial fan. For liquefaction susceptibility these units are placed in the same group.

Borehole logs describe soil characteristics of alluvium fan deposits in the cities of Beverly Hills and West Hollywood area as alternating beds of clay, silt, and fine- to medium-grained sand. Gravel is abundant in many layers. Compactness of sand layers range from loose to moderately dense as indicated by both lithologic descriptions and penetration tests performed during drilling. The thickness of this unit in this area ranges from zero to more than 20 feet.

The Quaternary alluvial deposits in the area of Ballona Gap westward to Venice are also described as alternating beds of clay, silt, and fine- to medium-grained sand. Fine-grained material becomes more dominant and gravel is less abundant in this region. Compactness of sand layers ranges from loose to moderately dense. The thickness of this unit in this area ranges from zero to more than 25 feet. Locally, in the old Ballona channel, the thickness may be 50 feet or greater. Younger alluvium in the lowlands near Ballona Creek was subdivided into “alluvium” and “floodplain” deposits by Castle (1960). Both of these units have soft clay and silt near the surface but the “alluvium” was described by Castle as being a veneer over older deposits. The geology map used in this report depicts these as Qya2.

From Westwood south and west to the City of Santa Monica, young alluvial sediments deposited on erosional surfaces consist of alternating beds of clay, sandy clay, silt, sandy silt, fine sands, and, locally, scattered gravel. The fine sands are described as loose to slightly compact. Borehole logs indicate that total thickness of these deposits ranges from a few feet to about 45 feet.

The available data imply that the alluvium deposited in the canyons, as well as in the narrow channels incised in older Quaternary alluvium, consists predominately of loose to moderately dense, poorly sorted clayey sand, silty sand, with gravel.

GROUND-WATER CONDITIONS

A ground-water evaluation of alluviated areas and canyons was performed in order to determine historically shallow ground-water levels in the Beverly Hills Quadrangle. Areas characterized by historical ground-water or perched water with depths of less than 40 feet are considered for the purposes of liquefaction zoning. Water depth data were obtained from the City of Beverly Hills Safety Element (Woodward-Clyde Consultants, 1987), compiled from geotechnical borehole logs, environmental monitoring wells, and water-well logs, some dating back to the turn of the 20th century (Mendenhall, 1905). The depths to first encountered water free of piezometric influences were plotted and contoured onto a map showing depths to historically shallowest ground water (Plate 1.2). This map was digitized and used for the liquefaction analysis.

The map was compared to other similar published maps as a check against any major discrepancies (Tinsley and others, 1985; Leighton and Associates, 1990). A depth to ground water map in the City of Santa Monica Safety Element (Leighton and others, 1994) shows water as shallow as 20 feet in the vicinity of Broadway Boulevard, Colorado Avenue, 26th Street, and Centinela Avenue. Several boreholes were examined in this area but no evidence was found for water this shallow.

Plate 1.2 shows that historical shallow water conditions (less than 40 feet depth) have existed in several areas of the Beverly Hills Quadrangle, namely from the West Hollywood area southwest to the eastern edge of Santa Monica, along the eastern and southern edges of the mapped area, and at the beach. Shallow water was encountered in boreholes in Santa Monica Canyon (just west, in the Topanga Quadrangle), and in Sepulveda, Benedict, Higgins, Franklin and Coldwater canyons.

PART II

EVALUATING LIQUEFACTION POTENTIAL

Liquefaction occurs in water saturated sediments during moderate to great earthquakes. Liquefied sediments are characterized by a loss of strength and may fail, causing damage to buildings, bridges, and other such structures. A number of methods for mapping liquefaction hazard have been proposed; Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of susceptibility units, and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to evaluate liquefaction potential. Liquefaction susceptibility is a function of the capacity of sediments to resist liquefaction and liquefaction opportunity is a function of the seismic ground shaking intensity. The application of the Seed Simplified Procedure (Seed and Idriss, 1971) for evaluating liquefaction potential allows a quantitative characterization of susceptibility of geologic units. Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for mapping liquefaction hazards in the Los Angeles region. The method applied in this study is similar to that of Tinsley and others (1985), combining geotechnical data analyses, and geologic and hydrologic mapping, but follows criteria adopted by the California State Mining and Geology Board (in press).

LIQUEFACTION OPPORTUNITY

According to the criteria adopted by the California State Mining and Geology Board (in press), liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for ground shaking strong enough to generate liquefaction. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10% probability of exceedance over a 50-year period. The earthquake magnitude is the magnitude that contributes most to the acceleration.

For the Beverly Hills Quadrangle, peak accelerations of and 0.45 g to 0.55 g resulting from earthquakes of magnitude 6.4 to 7.0 were used for liquefaction analyses. The PGA and magnitude values were derived from maps prepared by Petersen and others (1996) and Cramer and Petersen (1996), respectively. See the ground motion portion (Section 3) of this report for further details.

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of soils to loss of strength when subjected to ground shaking. Primarily, physical properties and conditions of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance. Soils that lack resistance (susceptible soils) are typically saturated, loose sandy sediments. Soils resistant to liquefaction include all soil types that are dry or sufficiently dense. Cohesive soils are generally not considered susceptible to liquefaction.

DMG's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil-property and soil-condition factors such as type, age texture, color, and consistency, along with historic depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, findings can be related to the map units. A qualitative susceptible soil inventory is outlined below and summarized in Table 1.1.

Older Marine Deposits (Qom?)

Older marine deposits generally have high blow counts. The materials are moderately dense to very dense fine sand and silty sand, stiff silt, and some clay. This unit is considered to have low liquefaction susceptibility.

Geologic Unit: Area	Sediment Type	Sand Consistency	Historic Depth to Ground Water	Liquefaction Susceptibility
Pre-Quaternary	Various			very low
Older marine (Qom?)	Sand, silty sand,silt and clay	Med. dense todense	20ft	low
Older alluvium (Qoa)	Sand, clay, siltwith gravel	Med. dense tovery dense	3 ft	low
Eolian (Qe)	Sand	Loose	17 ft	low (unsaturated)
Beach (Qm)	Sand	Loose	0 ft	high
Younger alluvium (Qya1, Qya2) Beverly Hills-West Hollywood	Clay, silt, sand,gravel	Loose to med.dense	5 ft	low to high
Younger alluvium (Qya1, Qya2) Ballona Gap and west	Clay, silt, sand	Loose to med.dense	10 ft	low to high
Younger alluvium (Qya1, Qya2) Westwood to Santa Monica	Clay, silt, sand	Loose to med.dense	20 ft	low to high
Younger alluvium (Qya1, Qya2, Qya) Canyon areas	Clayey sands, silty sand, gravel	Loose to med.dense	12 ft	high

Table 1.1. General geotechnical characteristics and liquefaction susceptibility of Quaternary alluvium and alluvial fan units, Beverly Hills Quadrangle.

Older Alluvial Fans

Based on the generally high blow counts recorded on the borehole logs, as well as the qualitative description of the materials as dense to very dense sands and silts, the older Quaternary alluvial fan deposits present in the Beverly Hills Quadrangle are considered to have low liquefaction susceptibility.

Eolian Deposits (Qe?)

Eolian deposits are very thin, less than 10 feet thick. These sediments are not saturated and, therefore, are considered to have low liquefaction susceptibility.

Beach Sand (Qm)

This loose sand is saturated and liquefied during the 1994 Northridge Earthquake (Stewart and others, 1994). The liquefaction susceptibility rating for this unit is high.

Younger Alluvium

Younger Alluvium–Canyons and Incised Channels (Qya, Qya1, Qya2)

Canyon and incised channel deposits contain layers of sand and silty sand described as loose to moderately dense. Where the younger alluvium is underlain by pre-Quaternary bedrock water is reported in some boreholes within 15 feet of the ground surface. Blow count data from a few boreholes drilled through these sediments indicate that the shallow sands are loose to moderate dense. Accordingly, these deposits are assigned a high liquefaction susceptibility rating.

Younger Alluvium (Qya1, Qya2)

Borehole log information indicates that these deposits contain much clay, which does not liquefy, but also contain some silts and loose sandy soils. Thus, where the deposits are saturated the liquefaction susceptibility is rated as high and, if not saturated, rated as low.

Quantitative Liquefaction Analysis

DMG performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; Seed and Harder, 1990; Youd and Idriss, 1997). This procedure calculates soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR) based on standard penetration test (SPT) results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses, expressed in terms of cyclic stress ratio (CSR). The factor of safety (FS) relative to liquefaction is: FS=CRR/CSR. FS, therefore, is a quantitative measure of liquefaction potential. Generally, a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, indicates the presence of potentially liquefiable soil. DMG uses FS, as well as other considerations such as slope, free face conditions, and thickness and depth of potentially liquefiable soil, to construct liquefaction potential maps, which then directly translate to Zones of Required Investigation.

More than half of the 200 borehole logs collected for alluviated areas in the Beverly Hills Quadrangle include blow-count data from SPTs or from penetration tests that allow reasonable blow count translations to SPT-equivalent values. Non-SPT values, such as those resulting from the use of 2-inch or 2 1/2-inch inside diameter ring samplers, were translated to SPT-equivalent values if reasonable factors could be used in conversion calculations. Few borehole logs, however, include all of the information (soil density, moisture content, sieve analysis, etc.) required for an ideal Seed Simplified Analysis. For boreholes having acceptable penetration tests, liquefaction analysis is performed using logged density, moisture, and sieve test values, or using average test values of similar materials.

LIQUEFACTION ZONES

Criteria for Zoning

The areas underlain by late Quaternary geologic units were included in liquefaction zones using the criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the California State Mining and Geology Board (in press). Under those criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historic earthquakes.

2. All areas of uncompacted fills containing liquefaction susceptible material that are saturated, nearly saturated, or may be expected to become saturated.

3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable.

4. Areas where existing geotechnical data are insufficient.

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historic high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (between 11,000 years and 15,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historic high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria for liquefaction zoning in the Beverly Hills Quadrangle is summarized below.

Areas of Past Liquefaction

Historic liquefaction has been reported (Stewart and others, 1994) in the beach deposits in Santa Monica (see Plate 1.2 for location) and these deposits are zoned as potentially liquefiable.

Artificial Fills

Non-engineered artificial fills have not been delineated or mapped in the Beverly Hills Quadrangle. Consequently, no areas are zoned for potential liquefaction relative to artificial fill.

Areas with Existing Geotechnical Data

Borehole logs that included penetration test data and reasonably sufficient lithologic descriptions were used to determine the liquefaction potential. Accordingly, these areas are zoned or not zoned according to the liquefaction potential based on adequate existing geotechnical data. Liquefaction analyses performed on data from a few boreholes drilled through younger alluvium of canyons and incised channel deposits indicate the shallow sands have factors of safety equal to or less than 1.0 for the anticipated earthquake shaking. In the younger alluvial deposits, most of the boreholes whose log data were analyzed using the Seed Simplified Procedure contain sediment layers that liquefy under the given earthquake parameters. These areas containing potentially liquefiable material are zoned.

Areas of Insufficient Geotechnical Data

Younger alluvium deposited in some canyon areas generally lack adequate geotechnical borehole information. The soil characteristics and ground-water conditions in these cases are assumed to be similar to deposits where subsurface information is available. These canyon deposits, therefore, are included in the liquefaction zone for reasons presented in criterion 4-a above.

ACKNOWLEDGMENTS

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the Beverly Hills 7.5-Minute Quadrangle, Los Angeles County, California

By

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PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Beverly Hills 7.5-minute Quadrangle (scale 1:24,000). This section and Section 1 addressing liquefaction, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Landslides triggered by earthquakes have historically been a major cause of earthquake damage. Landslides triggered by the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes were responsible for destroying or damaging numerous homes and other structures, blocking major transportation corridors, and damaging various types of life-line infrastructure. Typically, areas most susceptible to earthquake-induced landslides are on steep slopes and on or adjacent to existing landslide deposits, especially if the earth materials in these areas are composed of loose colluvial soils, or poorly cemented or highly fractured rock. These geologic and terrain conditions exist in many parts of southern California, most notably in hilly areas already developed or currently undergoing development. In addition, the opportunity for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region, which includes the Beverly Hills Quadrangle.

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered primarily from a variety of outside sources; thus the quality of the data is variable. Although the selection of data used in this evaluation was rigorous, the state of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Earthquake-generated ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. No attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the Beverly Hills Quadrangle, for more information on the delineation of liquefaction zones.

Information developed in the study is presented in two parts: physiographic, and geologic conditions in PART I, and ground shaking opportunity, landslide hazard potential and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The Beverly Hills Quadrangle covers approximately 62 square miles in southwestern Los Angeles County. Portions of the cities of Beverly Hills, Santa Monica, West Hollywood, Culver City, and Los Angeles, as well as unincorporated areas of Los Angeles County, lie within the quadrangle. The University of California Los Angeles (UCLA) campus is located just north of the center of the quadrangle, near the Los Angeles community of Westwood, about 11 miles west of the Los Angeles Civic Center.

The northern part of the quadrangle is dominated by hilly and mountainous terrain of the southern slope of the eastern Santa Monica Mountains, which contain peaks greater than 1600 feet in elevation. The crest of the west-trending Santa Monica Mountain range lies near the northern border of the quadrangle. Numerous steep-sided, north-trending ridges extend from the crest to the coastal plain of the Los Angeles basin. An older dissected alluvial surface, the Santa Monica plain, lies along the southern flank of the Santa Monica Mountains. This surface, which was formed by several large coalescing alluvial fans, has been eroded by streams draining the Santa Monica Mountains and backfilled with younger alluvium. Younger alluvial fans, which form part of the Hollywood piedmont slope, have been deposited on the older alluvial plain in the eastern part of the quadrangle.

The Baldwin Hills and Cheviot Hills extend from the southeast corner of the map toward Beverly Hills and represent the northernmost domal uplifts of the Newport-Inglewood structural zone. In the map area, the north slope of the Baldwin Hills rises more than 400 feet above sea level and has been deeply incised by erosion. The Cheviot Hills are characterized by moderately dissected, low rolling topography. In the southwest corner of the quadrangle, a slightly dissected older marine plain, the Ocean Park plain, extends from the ocean inland in the southern part of the City of Santa Monica and is believed to be a westward extension of the Cheviot Hills. Ballona Creek flows through Ballona Gap, which was formed by downwarping and subsequent erosion by local drainages and the ancestral Los Angeles River, between the Baldwin Hills and Cheviot Hills and continues along the southern edge of the Ocean Park plain, eventually exiting into Santa Monica Bay in the Venice Quadrangle.

Access to the Santa Monica Mountains is provided by numerous narrow residential streets, broader boulevards, and fire roads that follow north-trending canyons or ridgecrests between Sunset Boulevard on the south and Mulholland Drive, which follows the crest of the Santa Monica Mountains, on the north. The Santa Monica Freeway (I-10) traverses the area from west to east and the San Diego Freeway (I-405) cuts diagonally from southeast to northwest through the quadrangle.

Residential and commercial development is concentrated in the area south of the Santa Monica Mountains. Hillside residential development began in the 1920's and 1930's, grew rapidly after

World War II, and continues with several mass-grading projects today. Other current land uses include: parklands, sanitary landfills, oil fields, golf courses, and reservoirs, including Stone Canyon Reservoir and Franklin Canyon Reservoir.

GEOLOGIC CONDITIONS

Surface and Bedrock Geology

A recently compiled U.S. Geological Survey (USGS) geologic map was obtained in digital form (Yerkes, 1997) for the Beverly Hills Quadrangle. The contacts between bedrock and alluvium from the digital file were extensively modified to conform to the topographic contours of the USGS 7.5-minute quadrangle. Bedrock geology was also modified to reflect more recent mapping. In the field, observations were made of exposures, aspects of weathering, and general surface expression of the geologic units. In addition, the relation of the various geologic units to development and abundance of landslides was noted.

The oldest geologic unit mapped in the Beverly Hills Quadrangle is the Jurassic Santa Monica Slate, which is widely exposed in the northern part of the quadrangle where it forms rugged slopes in the Santa Monica Mountains. Locally, it consists of intensely jointed and fractured slate (Jsm) and phyllite (Jsp) with well-developed slaty cleavage and a thick weathered zone characterized by angular chips and thin slabs of slate surrounded by clay. The spotted slate (Jsms) contains abundant crystals of cordierite believed to have formed as a result of contact metamorphism of the Santa Monica Slate with granitic intrusions. Cretaceous granodioritic and quartz dioritic (Kgr) plutonic rocks are exposed in the northeast corner of the quadrangle where they form an irregular intrusive contact with the slate characterized by inclusions of slate and schist in the granite and numerous veins of quartz. Locally, at the surface, the granitic rocks are soft and crumbly due to weathering. Because of the fractured and deeply weathered nature of the slate and granitic rocks, they are prone to landslides and debris flows on moderate to steep slopes.

In the map area, Santa Monica Slate and Cretaceous granite are overlain unconformably by deep-marine clastic sedimentary rocks of the Cretaceous Tuna Canyon Formation (Kt), which consists of interbedded sandstone, siltstone, and pebble-cobble conglomerate. Overlying the Tuna Canyon Formation are the Paleocene and Eocene nonmarine clastic sedimentary rocks of the Simi Conglomerate and Las Virgenes Sandstone and marine fine-grained sandstones of the Santa Susana Formation (Colburn and Novak, 1989). Because of the map scale, all of the Paleocene and Eocene rocks are included in the Santa Susana Formation (Tss; Coal Canyon Formation of Yerkes and Campbell, 1979).

Other Tertiary bedrock formations include the shallow-marine clastic sedimentary rocks and volcanics of the middle Miocene Topanga Group and deep-marine biogenic and clastic rocks of the upper Miocene Modelo Formation. The Topanga Group consists of interbedded conglomerate, massive sandstone, concretionary shale and siltstone (Tt, undivided), and basalt flows (Tb). The Modelo Formation is composed of interbedded clay shale, siltstone, and sandstone (Tm) and massive, fine- to coarse-grained sandstone (Tms). These formations are prone to slope failure where bedding planes are inclined in the same direction as the slope.

The Benedict Canyon fault zone cuts diagonally through the eastern Santa Monica Mountains in a northeasterly direction. Bedrock along this zone is more susceptible to slope failure because it has been highly fractured and, in some areas, experiences increased pore pressures due to the impounding of ground water along the fault (Denison, 1994).

The Baldwin Hills are primarily composed of marine sediments of Pleistocene age. Stratigraphic correlation of Plio-Pleistocene and Quaternary strata within the Los Angeles basin is difficult because of rapid lateral facies changes resulting from fluctuations in the paleo-shoreline and the time-transgressive nature of the faunal assemblages (Quinn and others, 1997). Because of the current lack of well-defined Quaternary correlations and nomenclature, the formation designations used in this study for the Baldwin Hills area should be regarded as generalized and informal.

The oldest Quaternary unit mapped in the Beverly Hills Quadrangle is the lower Pleistocene Inglewood Formation (Qi; "A" formation of Castle, 1960a and 1960b), which is exposed on the northern slope of the Baldwin Hills. It is composed of thinly interbedded siltstone and fine sandstone deposited in a shallow marine environment. Unconformably overlying the Inglewood Formation, is the Pleistocene San Pedro Formation (Qsp; "B" formation of Castle, 1960a and 1960b), which consists of poorly consolidated, fine- to coarse-grained sand interbedded with thin beds and lenses of gravel deposited in a near-shore marine environment ("Qc" in Weber and others, 1982). Also included in this unit are fluvial sand and gravel with local beds of clayey silt ("Qb" in Weber and others, 1982). A reddish brown, well-cemented and resistant, locally pebbly or gravelly, silty sand caps some of the ridges in the southeast corner of the map and is designated older alluvium (Qoa; "Qf" in Weber and others, 1982; "cap deposits" in Castle, 1960a and 1960b).

Quaternary sediments covering the remainder of the Beverly Hills Quadrangle include older marine deposits (Qom) with interfingering continental sediments on the Ocean Park Plain and Cheviot Hills, older and younger alluvial-fan deposits at the margins of the Santa Monica Mountains and Baldwin Hills (Qof, Qoa, and Qya1), floodplain and stream deposits in the basin and the canyons (Qya1, Qya2, Qya), eolian deposits (Qe), and beach sand (Qm). Landslides (Qls and Qls?) are widespread in the Beverly Hills Quadrangle, occurring on steep slopes in the Santa Monica Mountains and the north slope of the Baldwin Hills. Modern man-made (artificial) fills (af) are also mapped in some areas. A more detailed discussion of the Quaternary deposits in the Beverly Hills Quadrangle can be found in Section 1.

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, they first must be ranked on the basis of their overall shear strength. Generally, the primary source for rock shear-strength measurements is geotechnical reports prepared by consultants on file with local government permitting departments. Shear strength data for the rock units identified on the geologic map were obtained from the City of Los Angeles, Department of Building and Safety (see Appendix A). The locations of rock and soil samples taken for shear testing are shown on Plate 2.1.

Shear strength data gathered from the above source were compiled for each mapped geologic unit, and subdivided for fine-grained and coarse-grained lithologies, if appropriate. Geologic units were grouped on the basis of average angle of internal friction (average f) and lithologic character. When available, shear tests from adjacent quadrangles were used to augment data for geologic formations that had little or no shear test information. If no shear test data were available from adjacent quadrangles, geologic units were added to existing strength groups on the basis of lithologic and stratigraphic similarities. Within the Beverly Hills Quadrangle, no shear tests were available for Tss, Qi, Qsp, af and all Quaternary alluvial units except for Qa. Shear test data for Qi and Qsp from the Venice and Hollywood quadrangles were used to assign these units to existing strength groups. The other units were added to existing groups on the basis of lithologic and stratigraphic similarities.

To subdivide mapped geologic formations that have both fine-grained and coarse-grained lithologies, we assumed that where stratigraphic bedding dips into a slope (favorable bedding) the coarse-grained material strength dominates, and where bedding dips out of a slope (adverse bedding) the fine-grained material strength dominates. We then used structural information from the geologic map (see “Structural Geology”) and terrain data in the form of slope gradient and aspect, to identify areas with a high potential for containing adverse bedding conditions. These areas, located on the map, were then used to modify the geologic material-strength map to reflect the anticipated lower shear strength for the fine-grained materials.

For the Beverly Hills geologic rock strength map, geologic formations within 100 feet of the Benedict Canyon Fault were judged to be altered by fault processes and were assigned to a rock strength category that is one level lower than non-faulted units.

The results of the grouping of geologic materials in the Beverly Hills Quadrangle are in Tables 2.1 and 2.2.

Structural Geology

Accompanying the digital geologic map (Yerkes, 1997) were digital files of associated geologic structural data, including bedding and foliation attitudes (strike and dip) and fold axes. We used the structural geologic information provided with the digital geologic map (Yerkes, 1997) and from Dibblee (1991) to categorize areas of common stratigraphic dip direction and magnitude, similar to the method presented by Brabb (1983). The dip direction category was compared to the slope aspect (direction) category and, if the same, the dip magnitude and slope gradient categories were compared. If the dip magnitude category was less than or equal to the slope gradient category, and the bedding dip was greater than 25% (4:1 slope), the area was marked as a potential adverse bedding area. This information was then used to subdivide mapped geologic units into areas where fine-grained and coarse-grained strengths would be used.

BEVERLY HILLS QUADRANGLE SHEAR STRENGTH GROUPS							
	Formation Name	Number Tests	Mean/Median Phi	Mean/Median (Group phi) (deg)	Group Mean/Median C (psf)	No Data: Similar Lithology	Phi Values Used in Stability Analysis
GROUP 1	Kgr Jsp TK Jsms Jms	39 18 4 39 37	37.8/38 36.5/37 35.9/35.7 35/36 34.2/34	35.6/36	659/475	Tb	35.6
GROUP 2	Tms(fbc) Tt(fbc) Kt Tm(fbc)	15 43 48 17	33.2/34 33/33 32.4/33 32.3/34	32.7/33	548/400	Tss	32.7
GROUP 3	Qa Tm(abc)	3 15	31.7/32 30.1/31	30.3/31.5	660/550	af, Qal, Qao, Qay1, Qay2, Qe?, Qi, Qm, Qoa, Qom?, Qt	30.3
GROUP 4	Tms(abc) Tt(abc)	5 16	28/29 26.8/27.5	27/28	712/600		27
GROUP 5	Qls						12

abc = adverse bedding condition, fine-grained material strength
fbc = fovorable bedding condition, coarse-grained material strength

Table 2.1. Summary of the shear strength statistics for the Beverly Hills Quadrangle.

SHEAR STRENGTH GROUPS FOR THE BEVERLY HILLS QUADRANGLE				
GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5
Kgr Jsm Jsms Jsp Tb TK	Kt Tm(fbc) Tms(fbc) Tss Tt(fbc)	af Aq Qal Qay1,2 Qe? Qi Qm Qoa Qom? Qt Tm(abc)	Qsp Qya1 Qya2 Tms(abc) Tt(abc)	Qls

Table 2.2. Summary of the shear strength groups for the Beverly Hills Quadrangle.

Landslide Inventory

The evaluation of earthquake-induced landsliding requires an up-to-date and complete picture of the previous occurrence of landsliding. An inventory of existing landslides in the Beverly Hills Quadrangle was prepared (Irvine, unpublished) by combining field observations, analysis of aerial photos, and interpretation of landforms on current and older topographic maps. The following aerial photos were used for landslide interpretation: Fairchild (1927), Fairchild (1928), NASA (1994), and USDA (1952/53). Also consulted during the mapping process were previous maps and reports that contain geologic and landslide data (Byer, 1987; Dibblee, 1991; Harp and Jibson, 1995; L.A. Dept. of Public Works, 1963; Sabins and others, 1992; Stone & Associates, 1973; CDWR, 1961; Cobarrubias, 1992; Hoots, 1930; Poland and others, 1959; Weber and others, 1982; and Weber and others, 1979). The completed hand-drawn landslide map was scanned, digitized, and the database was attributed with information on confidence of interpretation (definite, probable, or questionable) and other properties, such as activity, thickness, and associated geologic unit(s). A version of this landslide inventory is included with Plate 2.1.

PART II

EARTHQUAKE-INDUCED LANDSLIDE GROUND SHAKING OPPORTUNITY

Design Strong-Motion Record

The Newmark analysis used in delineating the earthquake-induced landslide zones requires he selection of a design earthquake strong-motion record. For the Beverly Hills Quadrangle, the selection was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by DMG for a 10% probability of being exceeded in 50 years (Petersen and others, 1996; Cramer and Petersen, 1996). The parameters used in the record selection are:

Modal Magnitude:	6.4 to 7.1
Modal Distance:	2.5 to 7.4 km
PGA:	0.46 to 0.55g

The strong-motion record selected was the Channel 3 (N35°E horizontal component) University of Southern California Station #14 recording from the magnitude 6.7 Northridge Earthquake (Trifunac and others, 1994). This record had a source to recording site distance of 8.5 km and a PGA of 0.59 g. The selected strong-motion record was not scaled or otherwise modified prior to analysis.

Displacement Calculation

To develop a relationship between the yield acceleration (a_y; defined as the horizontal ground acceleration required to cause the factor of safety to equal 1.0) and Newmark displacements, the design strong-motion record was integrated twice for a given a_y to find the corresponding displacement, and the process repeated for a range of a_y (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for any combination of geologic material strength and slope angle, as represented by the yield acceleration. We used displacements of 30, 15 and 5 cm as criteria for rating levels of earthquake shaking damage on the basis of the work of Youd (1980), Wilson and Keefer (1983), and the DMG pilot study for earthquake-induced landslides (McCrink and Real, 1996). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.076, 0.129 and 0.232g. Because these yield acceleration values are derived from the design strong-motion

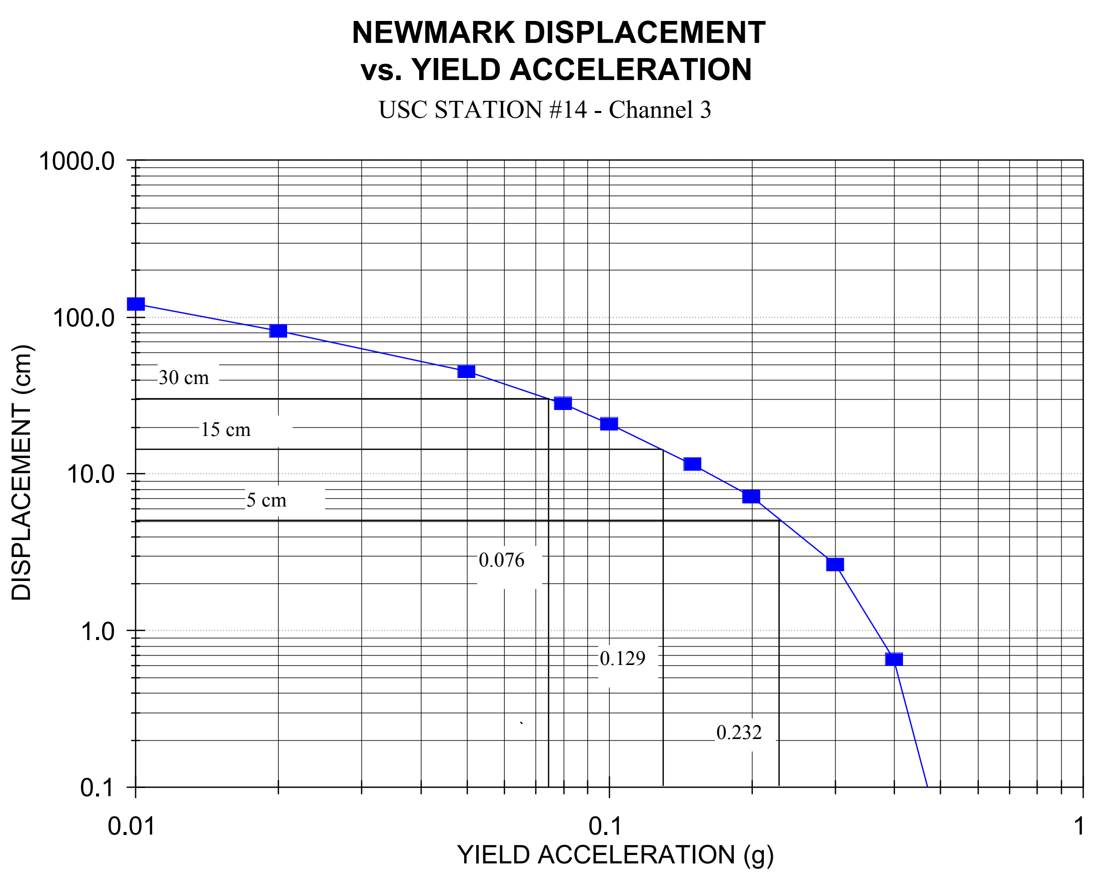

Figure 2.1. Yield acceleration vs. Newmark displacement for the USC Station # 14 strong-motion record from the 17 January 1994 Northridge, California Earthquake.

record, they represent the ground shaking opportunity thresholds that are significant to the Beverly Hills Quadrangle.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. To calculate slope gradient for the terrain within the Beverly Hills Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM, which was prepared from the 7.5-minute quadrangle contours, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy. A program that adds a pixel to the edges of the DEM was run twice to avoid the loss of data at the quadrangle edges when the slope calculations were performed. A peak and pit smoothing process was then performed to remove errors in the elevation points.

To update the terrain data to reflect areas that have recently undergone large-scale grading, graded areas in the hilly portions of the Beverly Hills Quadrangle, essentially the Santa Monica Mountains, were identified. Terrain data for these areas were obtained from an airborne interferometric radar (TOPSAR) DEM flown and processed in August 1994 by NASA's Jet Propulsion Laboratory (JPL), and processed by Calgis, Inc. (GeoSAR Consortium, 1995; 1996). These terrain data were also smoothed and filtered prior to analysis. Plate 2.1 shows those areas where the topography is updated to 1994 grading conditions.

A slope map was made from both the USGS DEM and the radar DEM using a third-order, finite difference, center-weighted algorithm (Horn, 1981). The USGS DEM was then used to make a slope-aspect map. The USGS slope map was used in conjunction with the aspect map and geologic structural data to identify areas of potential adverse bedding conditions. Both slope maps were used with the geologic strength map, reflecting graded and ungraded conditions, in the preparation of the earthquake-induced landslide hazard potential map.

Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of 1 degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by the calculation of yield acceleration from Newmark's equation:

$$a_y = (FS - 1)g \sin \alpha$$

where FS is the Factor of Safety, g is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite slope failure α is the same as the slope angle.

The yield acceleration calculated by Newmark's equation represents the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. The acceleration values were compared with the ground shaking opportunity, defined by Figure 2.1, to determine the earthquake-induced landslide hazard potential. Based on the criteria described in Figure 2.1 above, if the calculated yield acceleration was less than 0.076g, expected displacements could be greater than 30cm, and a HIGH (H on Table 2.3) hazard potential was assigned. Likewise, if the calculated a_y fell between 0.076 and 0.129g a MODERATE (M on Table 2.3) potential was assigned, between 0.129 and 0.232 a LOW (L on Table 2.3) potential was assigned, and if a_y were greater than 0.232g a VERY LOW (VL on Table 2.3) potential was assigned.

Table 2.3 summarizes the results of the stability analyses. The earthquake-induced landslide hazard potential map was prepared by combining the geologic material-strength map and the slope map according to this table.

BEVERLY HILLS QUADRANGLE HAZARD POTENTIAL MATRIX												
		SLOPE CATEGORY										
Geologic Material Group	**Mean Phi**	**I 0-14**	**II 14-19**	**III 19-29**	**IV 29-34**	**V 34-38**	**VI 38-44**	**VII 44-47**	**VIII 47-50**	**IX 50-58**	**X 58-64**	**XI >64**
1	35.7	VL	VL	VL	VL	VL	VL	VL	L	L	M	H
2	32.7	VL	VL	VL	VL	VL	L	L	L	M	H	H
3	30.3	VL	VL	VL	VL	L	L	M	M	H	H	H
4	27	VL	VL	VL	L	L	M	H	H	H	H	H
5	12	L	M	H	H	H	H	H	H	H	H	H

Table 2.3. Hazard potential matrix for earthquake-induced landslides in the Beverly Hills Quadrangle. Shaded area indicates hazard potential levels included within the hazard zone.

EARTHQUAKE-INDUCED LANDSLIDE ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (in press). Under those criteria, earthquake-induced landslide zones are areas meeting one or more of the following:

1. Areas known to have experienced earthquake-induced slope failure during historic earthquakes.

2. Areas identified as having past landslide movement, including both landslide deposits and source areas.

3. Areas where CDMG's analyses of geologic and geotechnical data indicate that the geologic materials are susceptible to earthquake-induced slope failure.

Existing Landslides

Studies of the types of landslides caused by earthquakes (Keefer, 1984) show that re-activation of the whole mass of deep-seated landslide deposits is rare. However, it has been observed that the steep scarps and toe areas of existing landslides, which formed as a result of previous landslide movement, are particularly susceptible to earthquake-induced slope failure. In addition, because they have been disrupted during landslide movement, landslide deposits are inferred to be weaker than coherent, undisturbed, adjacent source rocks. Finally, we felt that a long duration, San Andreas fault-type earthquake could be capable of initiating renewed movement in existing deep-seated landslide deposits. Therefore, all existing landslides identified in the inventory with a definite or probable confidence of interpretation were included in the hazard zone.

No earthquake-triggered landslides had been identified in the Beverly Hills Quadrangle prior to the Northridge earthquake. The Northridge earthquake caused a few small, shallow slope failures in the Beverly Hills Quadrangle (Harp and Jibson, 1995). Landslides attributed to the Northridge earthquake covered approximately 8 acres of land in the quadrangle. Of these landslides, 89% fall within the area of the hazard zone, based on a computer comparison of the zone map and the Harp and Jibson (1995) inventory.

Geologic and Geotechnical Analysis

On the basis of a DMG pilot study (McCrink and Real, 1996) the earthquake-induced landslide zone includes all areas determined to lie within the High, Moderate and Low levels of hazard potential. Therefore, as shown in Table 2.3, geologic strength group 5 is always included in the zone (mapped landslides); strength group 4 above 29%; strength group 3 above 34%; strength group 2 above 38%; and strength group 1, the strongest rock types, were zoned for slope gradients above 47%. This results in roughly 20% of the land in the quadrangle lying within the hazard zone.

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APPENDIX A

SOURCES OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
City of Los Angeles, Department of Building and Safety	**299**

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the Beverly Hills 7.5-Minute Quadrangle, Los Angeles County, California

By

Mark D. Petersen, Chris H. Cramer, Geoffrey A. Faneros, Charles R. Real and Michael S. Reichle

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included, are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5- minute quadrangle and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the “Simple

Prescribed Parameter Value" method (SPPV) described in the site investigation guidelines (California State Mining and Geology Board, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 and 2, addressing liquefaction and earthquake-induced landslide hazards, constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the seismogenic sources as published in the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology, and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10% probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

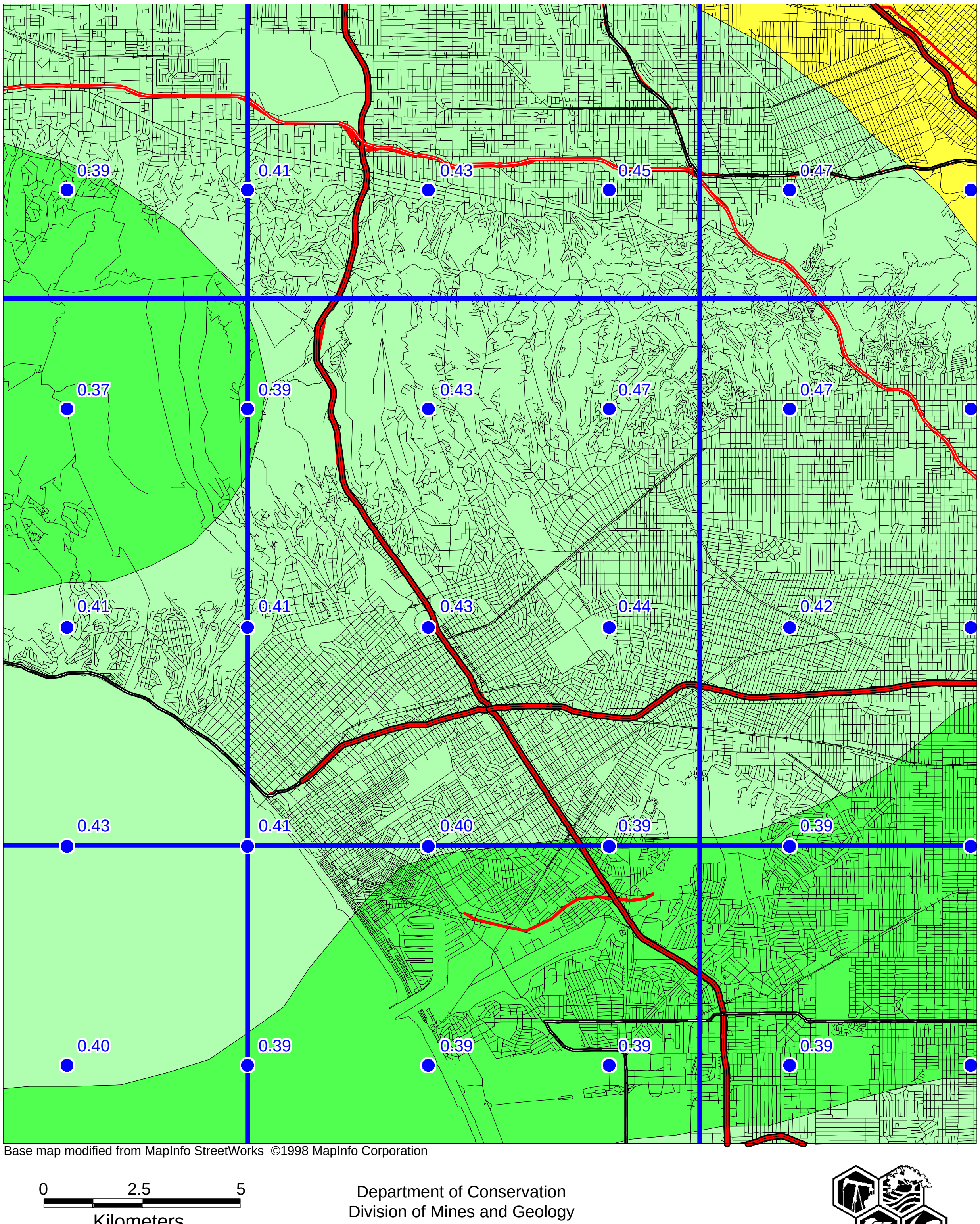
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight adjacent quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion

BEVERLY HILLS 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Department of Conservation
Division of Mines and Geology

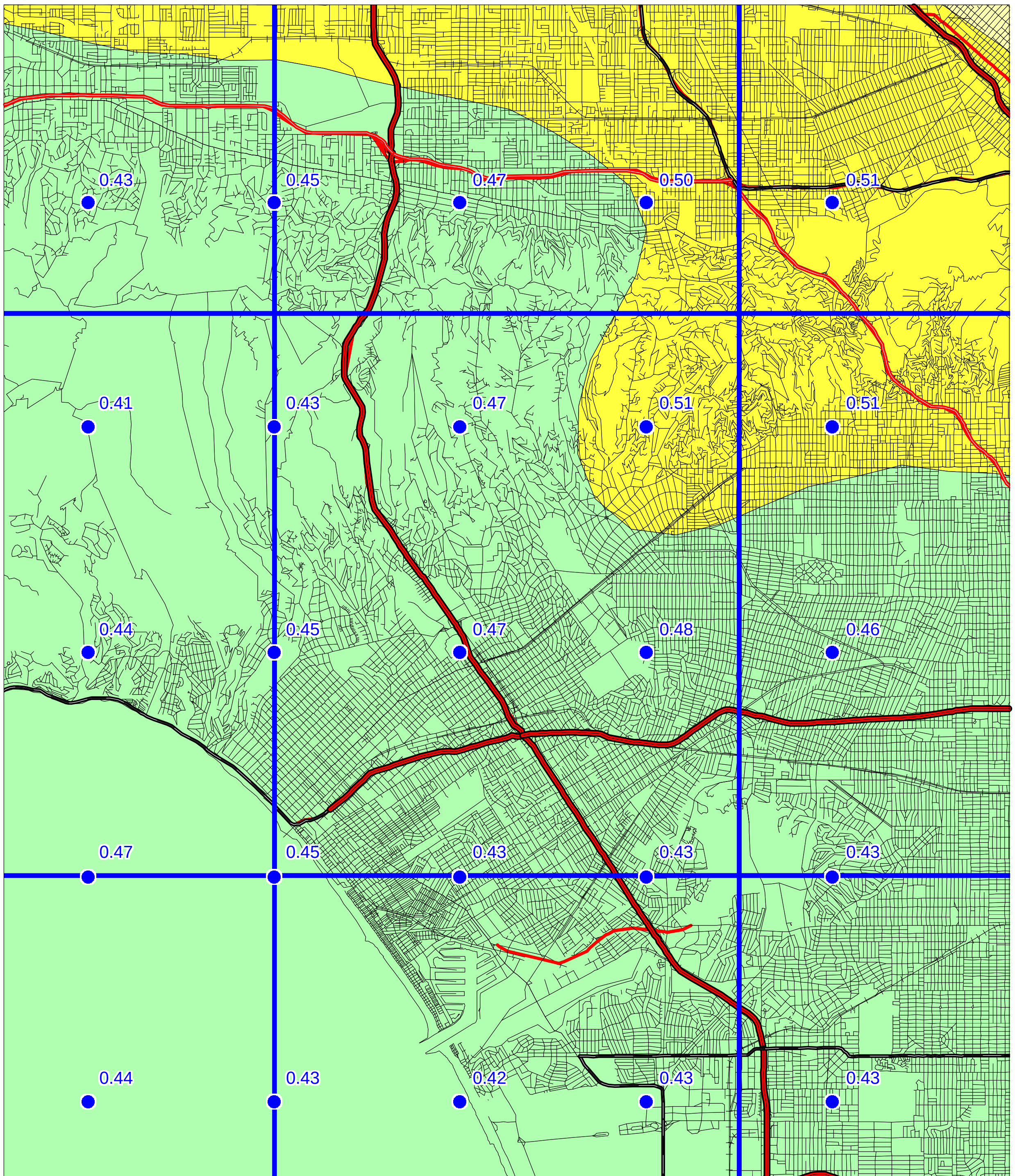
Figure 3.1

BEVERLY HILLS 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

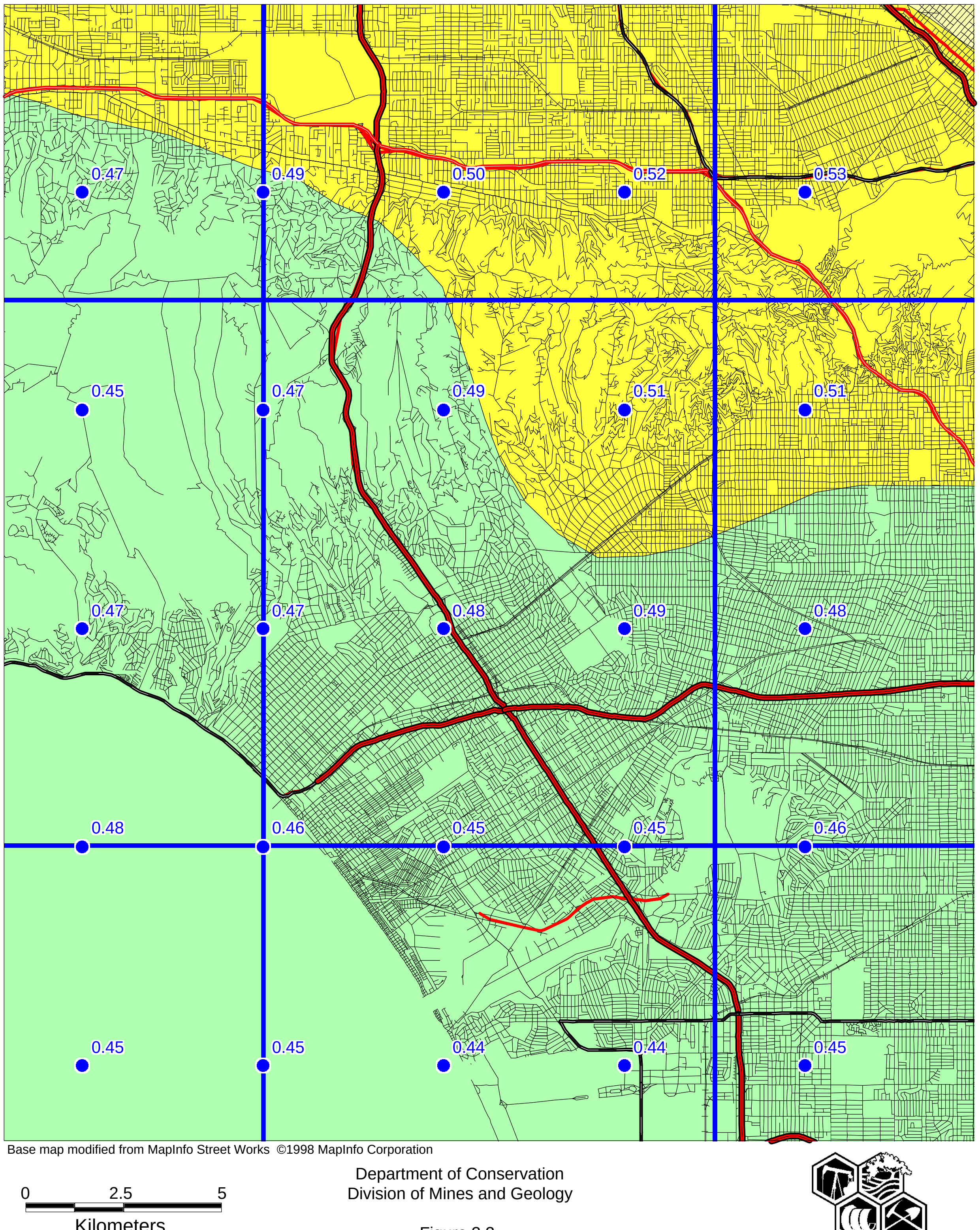
Figure 3.2

BEVERLY HILLS 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

ALLUVIUM CONDITIONS



Department of Conservation
Division of Mines and Geology

Figure 3.3

values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10% probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.

BEVERLY HILLS 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

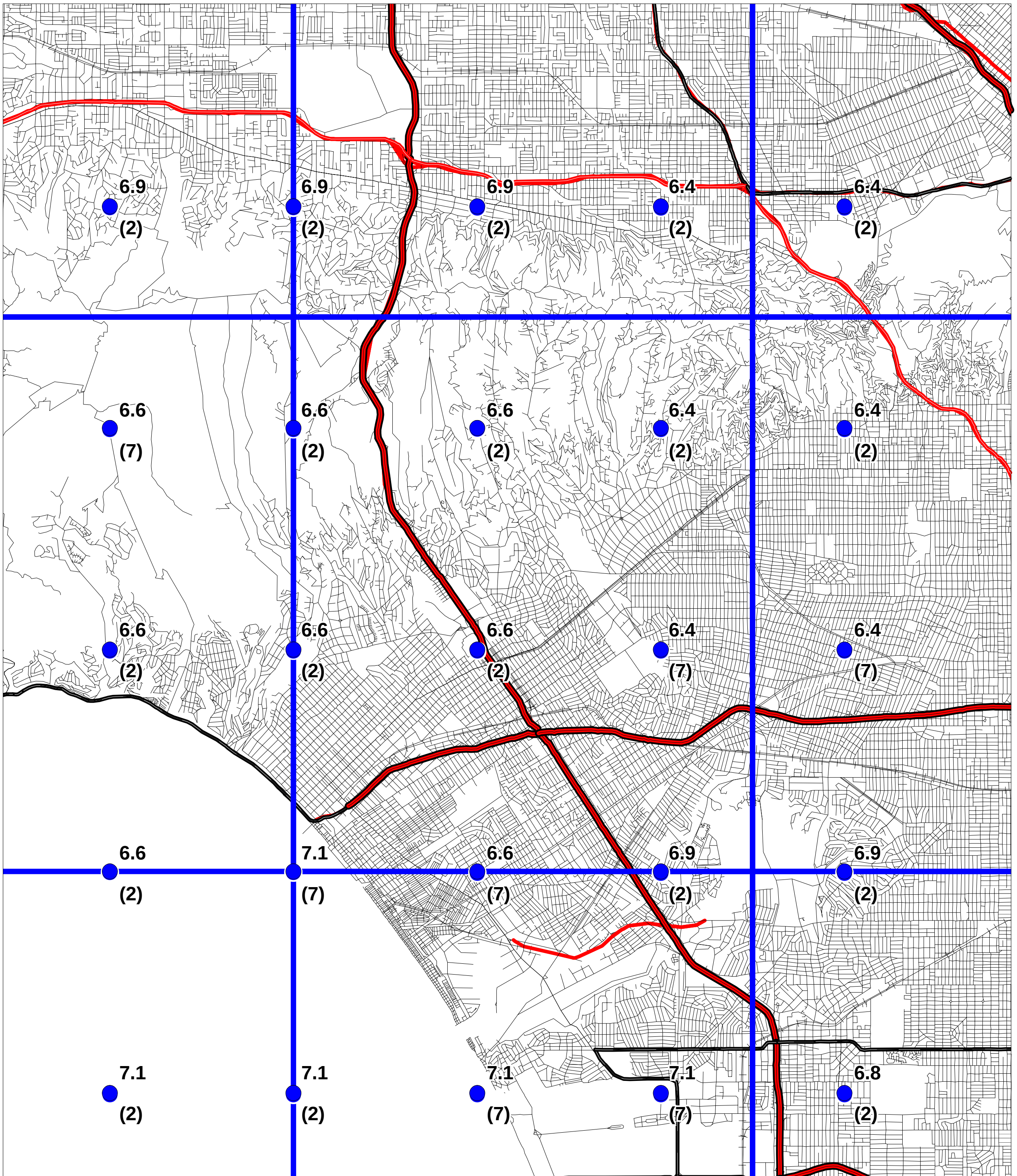
10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE

Magnitude (Mw)

(Distance (km))



Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

Figure 3.4

2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.

3. Uncertainties in the hazard values have been estimated to be about +/- 50% of the ground motion value at two standard deviations (Cramer and others, 1996).

4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not previously been recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.

5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (California State Mining and Geology Board, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the “importance” or sensitivity of the proposed building with regard to occupant safety.

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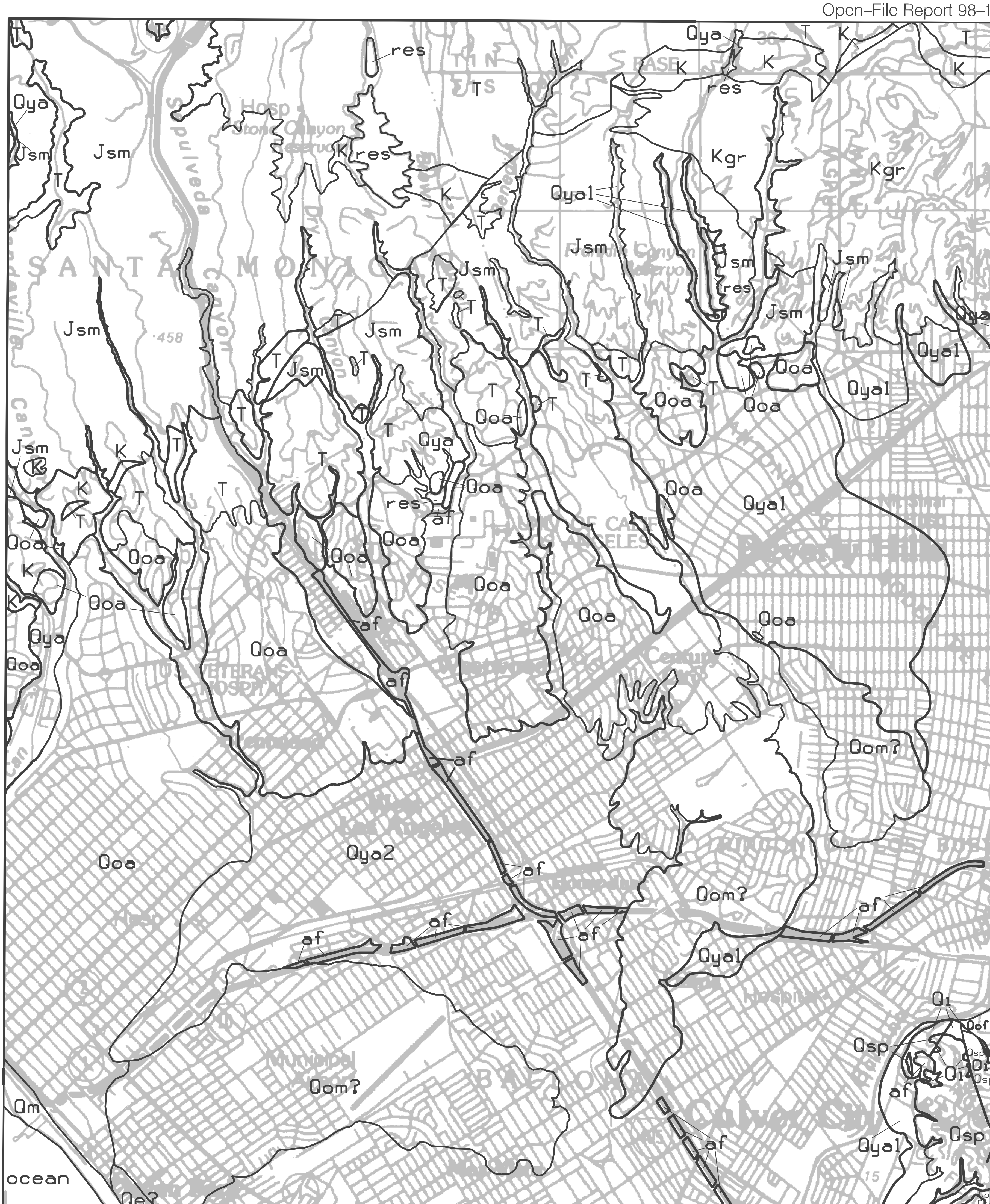


Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 1.1 Quaternary Geologic Map of the Beverly Hills Quadrangle.

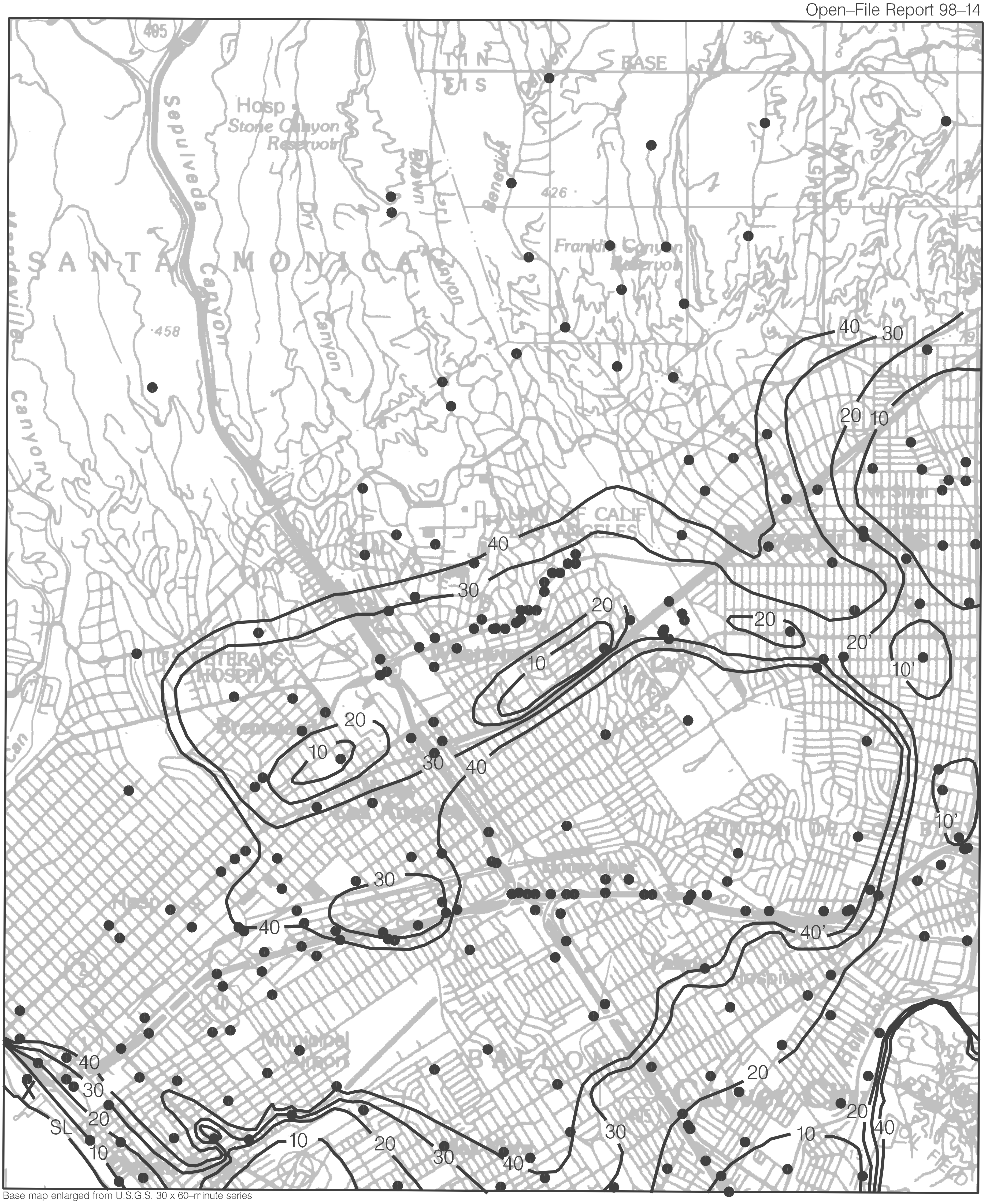
See Geologic Conditions section in report for descriptions of the units.

Pre–Quaternary rocks include:

Jsm = Jurassic Santa Monica Slate
K = Cretaceous sedimentary rocks
Kgr = Cretacieous granitic rocks
T = Tertiary rocks
res = reservoir.

ONE MILE

SCALE



Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 1.2 Historically Highest Ground Water Contours and Borehole Log Data Locations, Beverly Hills Quadrangle.

● Borehole Site

30 Depth to ground water in feet

X Site of historical earthquake–generated liquefaction. See "Areas of Past Liquefaction" discussion in text.

ONE MILE

SCALE

Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 2.1 Landslide inventory, Shear Test Sample Locations, Beverly Hills Quadrangle.

● shear test sample location landslide areas of significant grading

ONE MILE

SCALE